Modelling of FMCW Radar at 10 GHz

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Abstract— Full form of RADAR is Radio Detection and Ranging. In general, radar systems are an electromagnetic system which sends energy to search for target. It will reflect the portion of this energy back to the radar called as echoes. FM-CW radar is a Frequency Modulated Continuous Wave radar which is a special type radar. FMCW radar is simple in design, small in size and weight and uses low transmitting power. In this project we will be doing Modeling and Implementation of 10-GHz FMCW Height Measurement Device in MATLAB to find different parameters such as distance between the UAV and ground, path loss, SNR, noise figure, output power, losses etc. operating at 10 GHz. And it also includes the digital signal processing that to be performed on the signals obtained during range estimation of FMCW radar which is obtained after modeling and simulation.

Keywords— 10 GHz FMCW Radar, Simulink modelling, Signal processing, Frequency synthesizer.

I. INTRODUCTION

The word radar is a full form of Radio Detection and Ranging. The Devices such as accelerometers, radars, and cameras are typical devices for fall detection. Accelerometers have low life because of its mechanical structure and camera is not work well in low light. Hence in that radar is better choice than accelerometers and cameras. The radar transmits energy with high power to search for targets. Radars are classified by the types of waveforms or their operating frequency.

First based on the waveforms, radars can be Continuous Wave or Pulsed Radars. CW radars are continuously transmits high frequency signal. Continuous wave radar further classified in to two types such as modulated Continuous wave radar and unmodulated Continuous wave radar. The radar in this project is FMCW radar. FMCW radar is Frequency Modulated Continuous Wave radar which radiates high power continuously. In contrast to continuous wave radar, FMCW radar changes its frequency during the measurement.

Continuous wave radar devices have the disadvantages that it cannot measure the distance, it can measure only speed. Component needed to construct FMCW radar are an oscillator, amplifiers, power divider, a mixer, and antennas. In FM-CW radar transmitted signal is modulated in frequency and constant in amplitude. Thus, FMCW radar is recently used in a variety of applications, such as proximity fuses, Radio altimeters, Systems for detecting mobile targets. In this paper our aim is to Model and Implement 10-GHz FMCW radar Height Measurement Device (30m) and the digital signal processing that to be performed on the signals obtained during range estimation of FMCW radar which is obtained after modeling and simulation.

II. RELATED WORK

The Author S. Scherr etc. Describes in [1] that 122 GHz of FMCW radar is used with 1 GHz bandwidth to take measurement of two targets. Evaluation of FMCW a FFT based method is used. The Author Y. Zhu describes in the paper [2] that a frequency synthesizer using phase-locked loop technique is used. The Author T. Styles describes in the paper of [3] that FPGA Based design and implementation of a signal processing module for FMCW radar was done. The Author H. Eugin describes in the paper [4] various platforms such as the ACR102 has been implemented in a Xilinx Zynq device. The author E. Avignon-Meseldzija describes in the paper [5] that the frequency synthesizer is used to generate digital low frequency reference. The Author W. Chang describes in paper of [6] they have used universal DSP- 'PMS320C6416 which is fastest one processor to implement a real FMCW radar signal processing system. The author Yun-Taek Im etc. Describes in paper [7] that they have design PLL based FMCW radar. They have used DSP processor in radar system is TMS320C6713B.

III. ORGANIZATION OF PAPER

Organization of paper is as follows, Section A is discusses the basic radar equations such as, SNR, bit frequency, radar cross section etc. Section B discusses the basic of FMCW radar. Section C discusses the signal processing methods. Section D discusses ADC which is used in modelling of FMCW radar. Section E discusses Hardware and Software part which is used in proposed work. Section IV discusses simulation and implementation of FMCW radar.

A. RADAR EQUATIONS

Radar equations are as follows:

1. SNR:

SNR=Ps/PN

SNR=PTGTGRλ2σ/(4π3)R4kT0BFnL

Where,

- SNR is the signal to noise ratio
- PS is the signal power.
- PN is the noise power.
- PT is the transmit power.
- GT is the gain of the transmit antenna.
- GR is the gain of the receive antenna.
- λ is the wavelength of radar.
- σ is the cross section of radar.
- R is the distance from the radar to the target.

2. Distance resolution [1]

$\Delta R=C_0/2B$

Where,

- ΔR is range resolution.
- C_0 is speed of light.
- B is Bandwidth.

3. Bit Frequency:

F=B2R/TC0

- F is bit frequency
- C_0 in speed of light
- R is distance.
- T is sweep time

4. Radar cross section:

Radius=Range*θ (radian)

Area=π*(Radius)2

σ =10log (area)

B. FMCW RADAR

In FMCW radar the transmitted signal is modulated in frequency. The advantage of FMCW radar is that it can determine height accurately. Another advantage is continuous wave transmission, which allows to transmits high power signal continuously for distance measurement with low output power. In FMCW radar, a signal is transmitted for certain duration. When the signal is transmitted, the portion of reflected energy called echoes are received by the receiver and mixed with the transmit signal. The sweep may be from lower to higher frequencies, from higher to lower frequencies or do both successively. It can conclude that the FMCW radar is very good for detection at near ranges, and the industry has started to discover this by now using it in several commercial products. Some examples are collision detection radars for cars, altitude measurement and near obstacle ship navigation. FMCW radar

The distance R to the reflecting object can be determined by the following relations:

$R = C_0 \cdot T_d\ / 2$

Where:

- C_0 = speed of light = 3·108 m/s
- T_d = delay time in second.
- R = distance between antenna and the reflecting object.

$F/B=T_d/T$

Where:

- F is bit frequency.
- T is sweep time.
- B is Bandwidth.
- T_d is delay time.

$R=C_0\,TF/2B$.

Here,

R=K.F

Where,

- $K=C_0T/2B$

Here range is directly proportional to the bit frequency. In this the bandwidth is 75 MHz, range is 30 meter and the sweep time is 100 µsec. The target has a radial speed with respect to the receiving antenna, then the reflected signal gets a Doppler frequency f_D. The radar measures not only the difference frequency Δf but additional a Doppler frequency f_D.

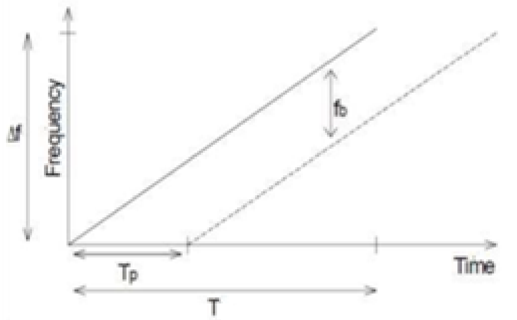

Fig 1: Ranging with an FMCW system

In fig.1 shows a transmit signal and which is return from the target. Δf is Bandwidth of the transmitted signal. T_p is delay time between transmitted signal and received signal. f_b is bit frequency, T is sweep time. At any instant, transmit and receive signals are given to the mixer. After multiplying this two signals result of mixer is sum and difference, then this signal is passed through low pass filter. The frequency of the signal is given by bit frequency.

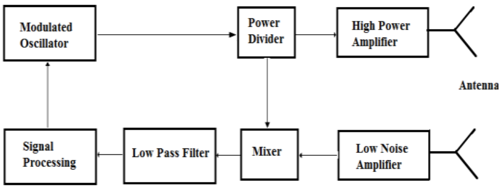

Fig 2: General Block diagram of FMCW radar

Fig 2 shows the general block diagram of FMCW radar. An oscillator is the device that used to generate an RF signal. Voltage control Oscillator (VCO) is the device that generates the RF signal. Here we are using frequency synthesizer to generate 10 GHz signal. PLL is used as a frequency synthesizer [4]. PLL can construct from the blocks such as a phase detector, filter, and VCO. A power divider splits the power exerted at one port into multiple paths. Antennas radiate energy into the air. The antenna for this project is the patch antenna. A patch antenna or microstrip antenna is a narrowband, wide-beam antenna. LNA is Low Noise Amplifier, which increases the power of the signal and the noise at input of the amplifier. LNAs are minimizing additional noise. Transmitted signal and received signal are mixed with mixer. There are two types of mixers are up conversion mixer down conversion mixer. Up conversion mixer mixes the local oscillator frequency and the intermediate frequency and produces the higher radio frequency. Down conversion mixer mixes the radio frequency and local oscillator frequency and produces the lower intermediate frequency. This project used down conversion mixer where the signal at input port is local oscillator signal and the signal from the receive antenna. A low pass filter that could be constructs using lumped element. It is used to filter out high frequency signal and pass lower frequency signal. Analog to digital is a system that converts an analog signal. The signal processing terminal must embody the three cornerstones of the successful product as a whole: efficiency, portability, and feasibility. The coherent detection and A/D transformation is the first steps of digital signal processing. ADC's are aimed at converting the analog signals which are received from the radar to digital signals. Then processed with the digital signal processing. We usually focus on the FFT brings in a practical application. In the processing procedure, we use FFT to estimate the frequency F_b of frequency difference signal.

C. THE SIGNAL PROCESSING METHOD

After Analog to digital converter the digitised signal is processed with digital signal processing. Advantages of digital signal processing are that they are simple, fast and accurate. Steps for digital signal processing of the waveform are as, 1) Fast Fourier transform (FFT) which transmits the time domain signal into frequency domain signal. 2) Filtering 3) Detection Rules 4)Multiple object Detection. Digital signal processing is used to extract the targets and also used to separate the two targets which is close to each other.

FFT (Fast Fourier Transform)

DFT is Discrete Fourier Transform which is a powerful mathematic tool to analyse the spectrum of digital signals. FFT is Fast implementation as compare to DFT. For N-points DFT, we require N multiplications and N-1 additions which are very complex. DFT requires order (N^2) calculations. FFT is an efficient algorithm for calculation of DFT. It require order (N log N) calculations. In this we discussed that, we use FFT to estimate the frequency Fb of frequency difference signal. If the length of FFT is N, then the frequency resolution is Δf= fs/N, where fs is sampling frequency and the distance resolution is ΔR=C/2Δf.

D. ADC

The data is captured using an ADC. A/D transformation is the first steps of digital signal processing. First analog signal which is received from FMCW radar converted to digital signal. Then processed with the digital signal processing. Here we have select the ADC is ADS 8329. It is high speed SAR type of ADC which gives serial interfacing with resolution is 16 bit.

E. Hardware and software

In this paper we are using simulink tools to implement the FMCW radar. After sampling through analog-to-digital converter (ADC), the IF signal is processed with DSP based signal processing board. A low cost and low power consumption DSP processor TMS320C6713 device has used for digital signal processing [6]. It runs at the clock rate of 250 MHz in this system. Flash storage chips and SDRAM chips are equipped around the processors for data initialization and expanding the on-chip RAM, respectively.

IV. SIMULATION AND IMPLEMENTATION

A. Signal Generation of 10GHz

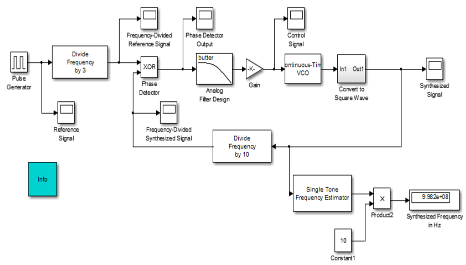

Figure 3: Signal generation of 10GHz using PLL

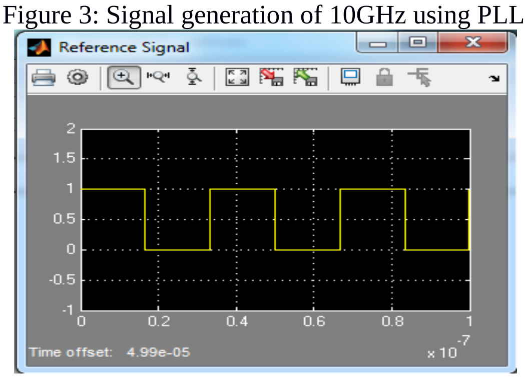

Figure4: Reference signal at 30 MHz

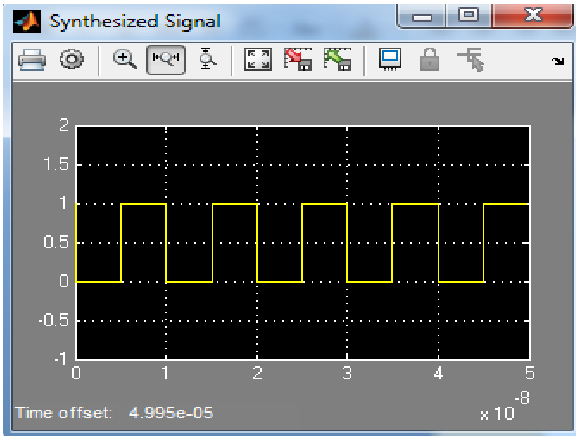

Fig 5: Synthesized signal at 10 GHz

B. Generation of IF Signal

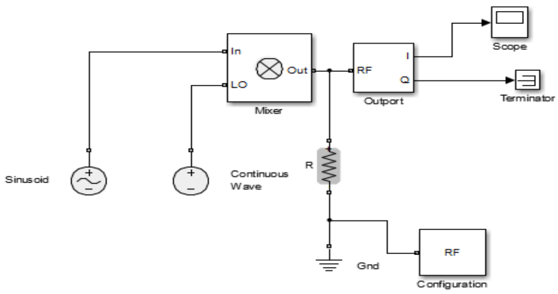

Fig 6: Generation of IF signal using down converter mixer

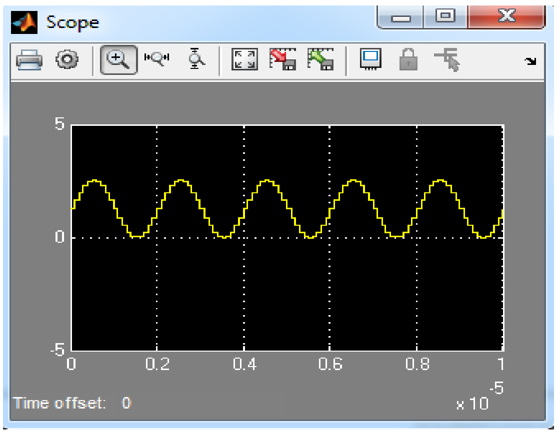

Fig 7: IF signal at 100KHz

V. CONCLUSIONS

FMCW radar has high accuracy range measurement. We are modelling a 10 GHz FMCW radar system for proximity fuze application. This paper presents a simulation of FMCW radar in simulink and study of [9] implementation of the FFT algorithm for the FMCW radar system. Here we have generate 10 GHz of signal using PLL and using mixer we have generate IF frequency of range 50 KHz to 500 KHz. The FFT can provide fast calculations as compare to DFT. Interfacing of high speed of ADC is required for digital signal processing.

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